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Simple electrodynamic transduction scheme for micromechanical resonators

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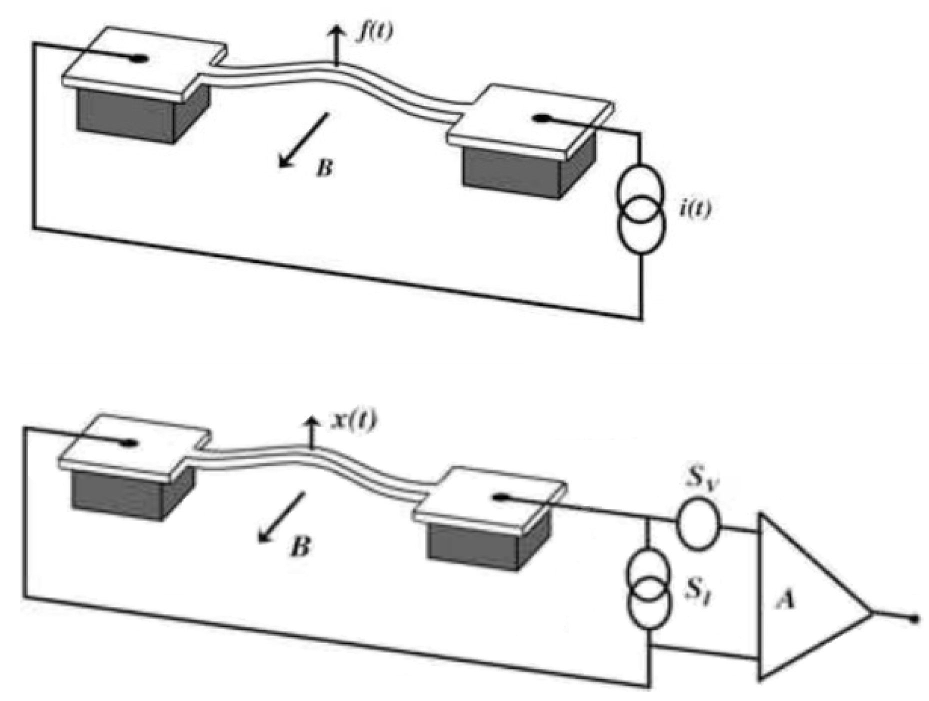
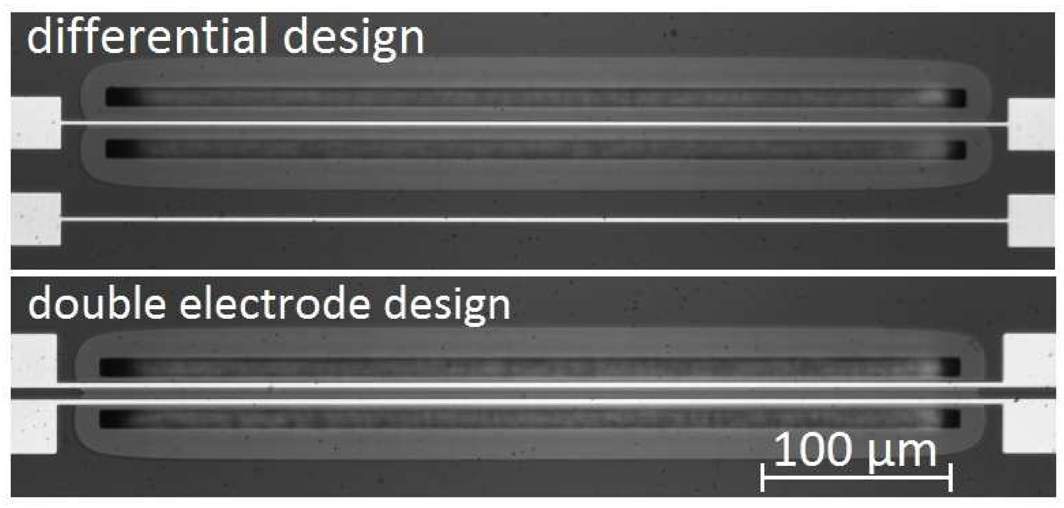
Introduction

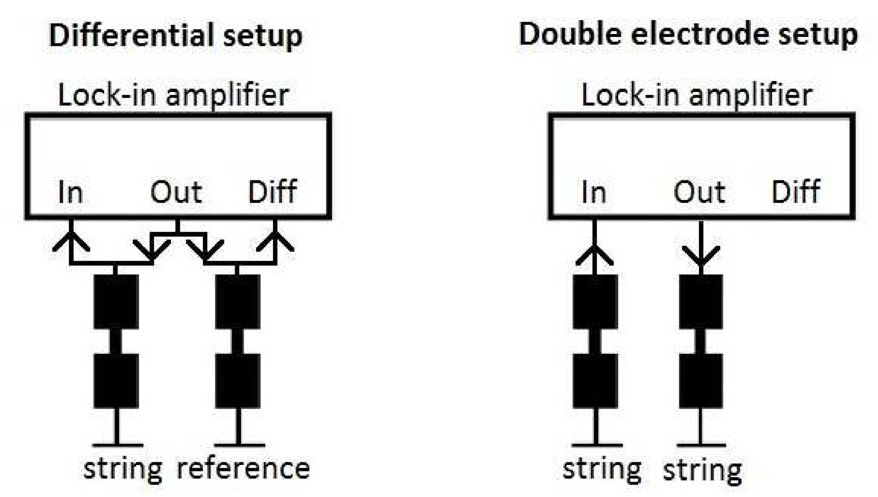
Resonators in micro- and nanoscale are subject of extensive research, especially because of their vast possible applications as e.g. ultrasensitive mass sensors. The working principle of such sensor is based on measuring the resonance frequency shift of vibrating structure. Apart from the design of the resonator itself, the actuation (Lorentz force, electrostatic, piezoelectric, thermoelastic) and readout (electromotive, capacitive, optical, piezoelectric, piezoresistive) techniques have a great influence on the whole sensor system. Among all of them, the electrodynamic transduction scheme is the one that offers low complexity and good performance. Here Lorentz force is used for actuation while induced electromotive force enables readout as micromechanical resonator with alternating current is placed in the static magnetic field [1].

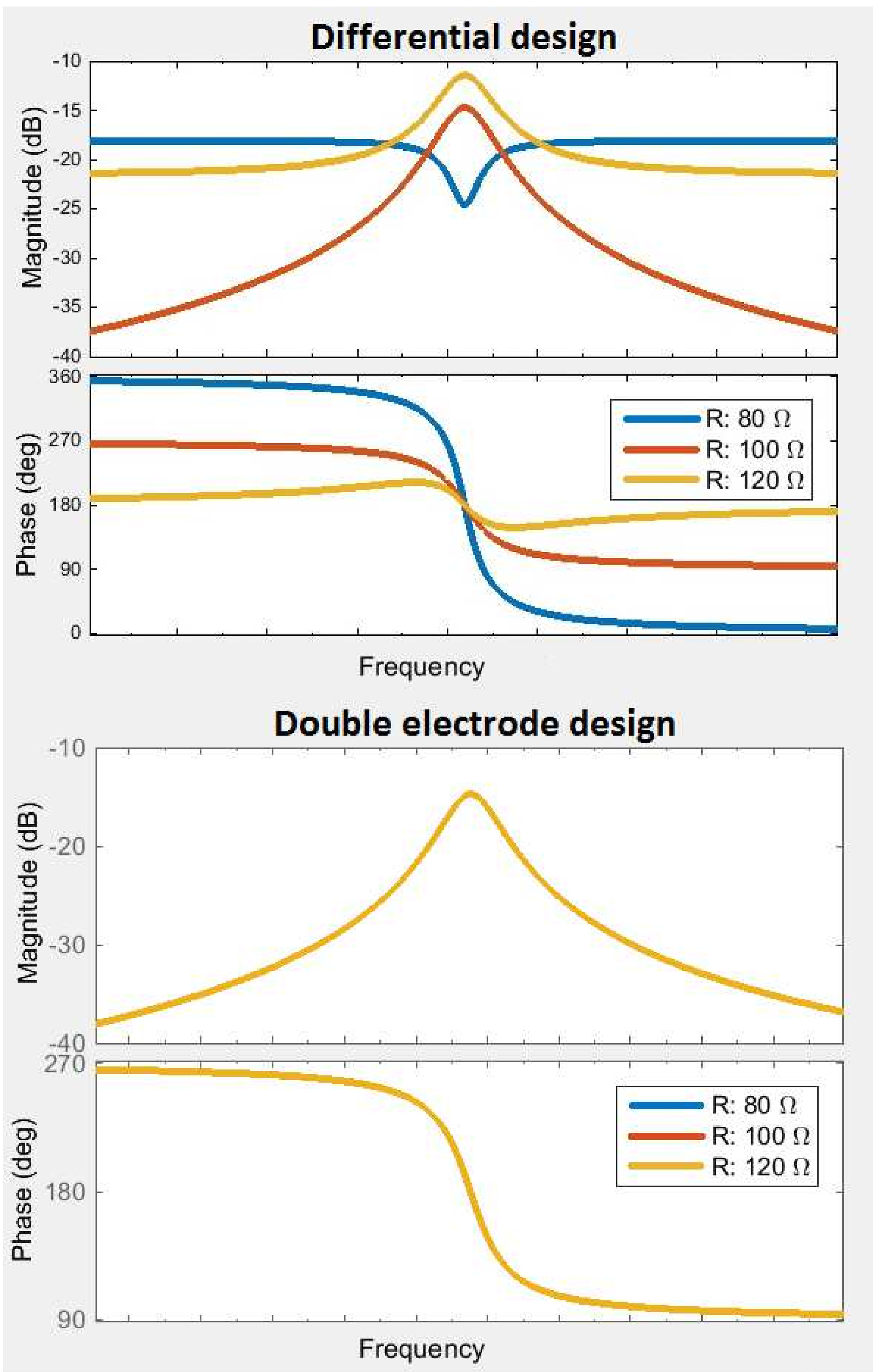


Electrodynamic Transduction Scheme

The electrodynamic transduction scheme was used from the very beginning of the research on nanomechanical resonators [2] and is already well developed. However there is still a lot of space for improvement, particularly in terms of simplifying experimental setup. Typically, the actuation and the readout is done via a single transducing electrode and one reference electrode *(differential design).* But this requires a rather complex differential design to extract the small induced electromotive readout current from the strong driving signal background. Therefore an alternative design with two transducing electrodes *(double electrode design)* was created in order to separate the readout and actuation signal paths. The differential scheme is no longer necessary which leads to much simpler experimental setup.





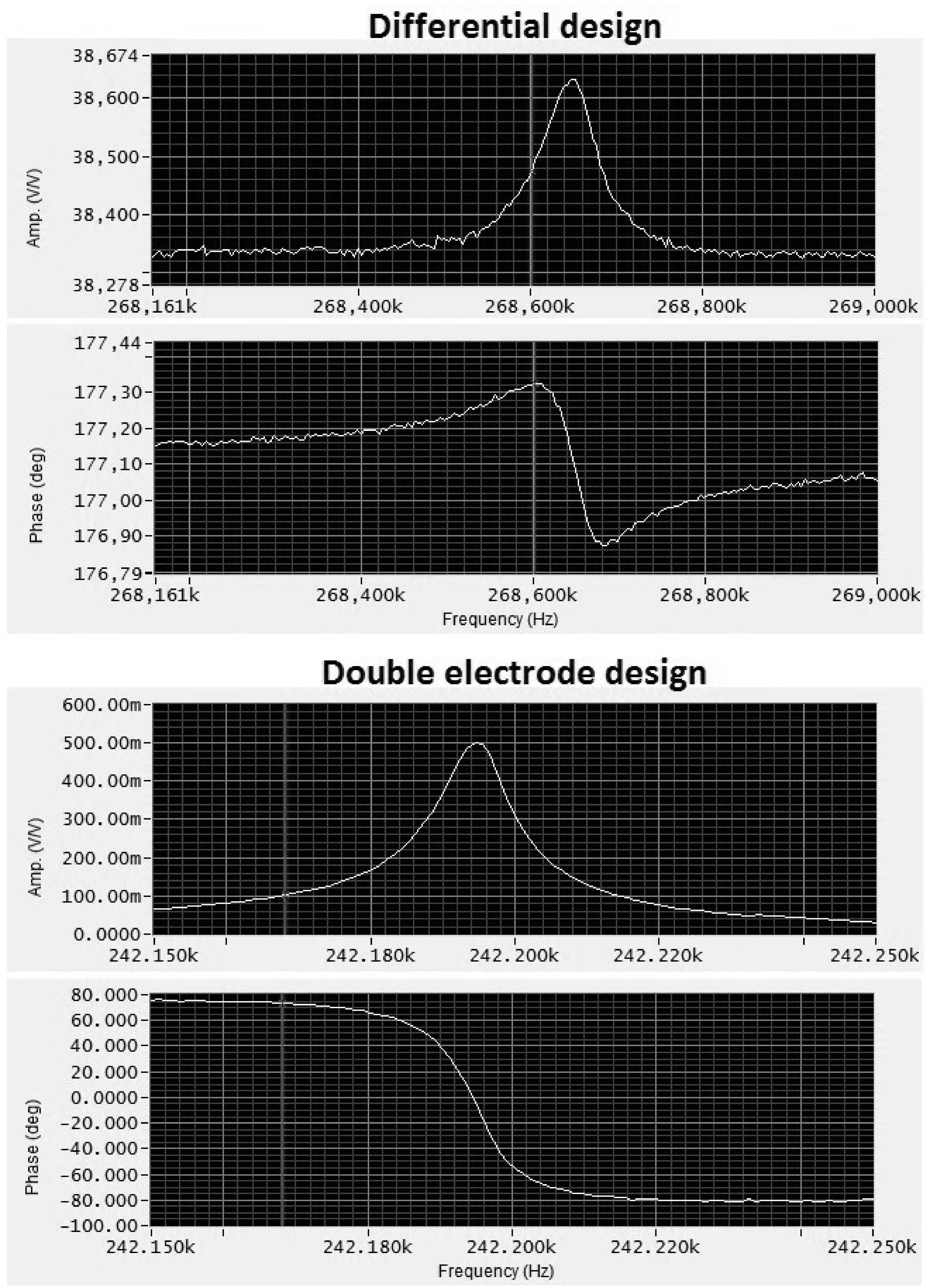


Simulations

Both transducing electrodes in the *double electrode design* are directly connected to the measurement equipment (lock-in amplifier) while setup for the *differential design* requires additional electronic components. This is mainly due to the resistance mismatch in between the transducing and reference electrodes. In order to make the two resistances as close to identical as possible the finely-tunable circuit must be developed containing adjustable phase shifter, variable amplifier and directional coupler [3].
The importance of electrode resistance balancing can be clearly seen in the simulations. Developed simulink model shows three resonance responses of transducing electrode with measured resistance of 100 Ω for varying reference electrode resistances. It is obvious that efficient resistance matching is crucial for obtaining reliable experimental results. This problematic issue is eliminated for the *double electrode design*.

Experimental results

Results are in good qualitative agreement with the simulations, in this case the resistance difference between electrodes in both designs is 10 Ω. At driving voltage of 10 µV, despite the close proximity (6 µm) of the two electrodes no capacitive crosstalk has been observed.



Summary

A simple approach for the electrodynamic transduction of micromechanical resonators is developed. A new chip design with two electrodes sitting on a string resonator allows to separate drive and detection signal. Like that the troublesome differential measurement scheme can be avoided, which significantly simplifies the experimental setup. Next efforts would be focused on further characterization and optimization of this novel scheme.

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[3] X. L. Feng, C. J. White, A. Hajimiri, M. L. Roukes, Nature Nanotech. 3 (2008) 342–346.